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Expressivity and Reasoning:
Examples in Geologic Time and Mineral Observations

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Tetherless World Constellation
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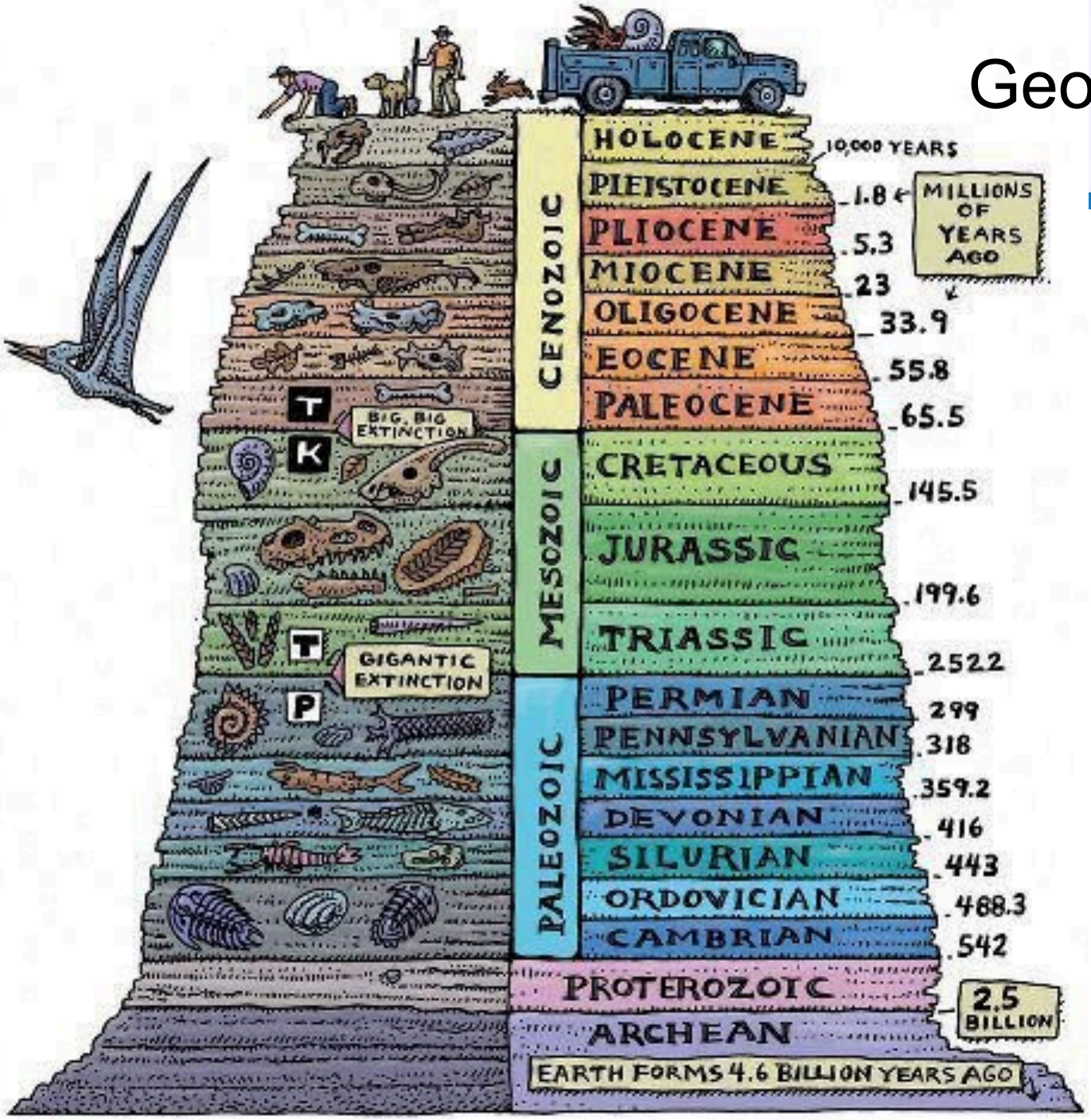
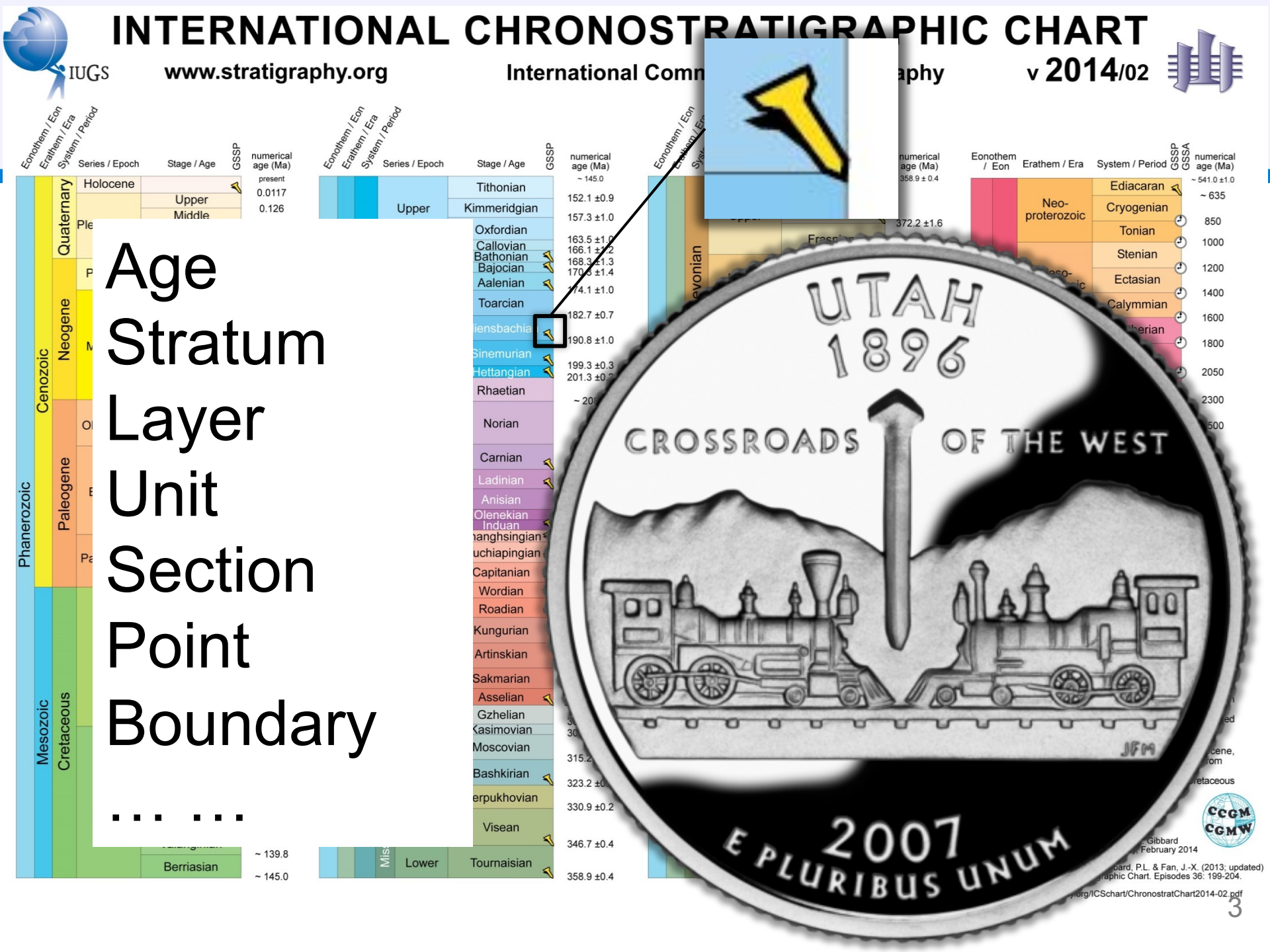
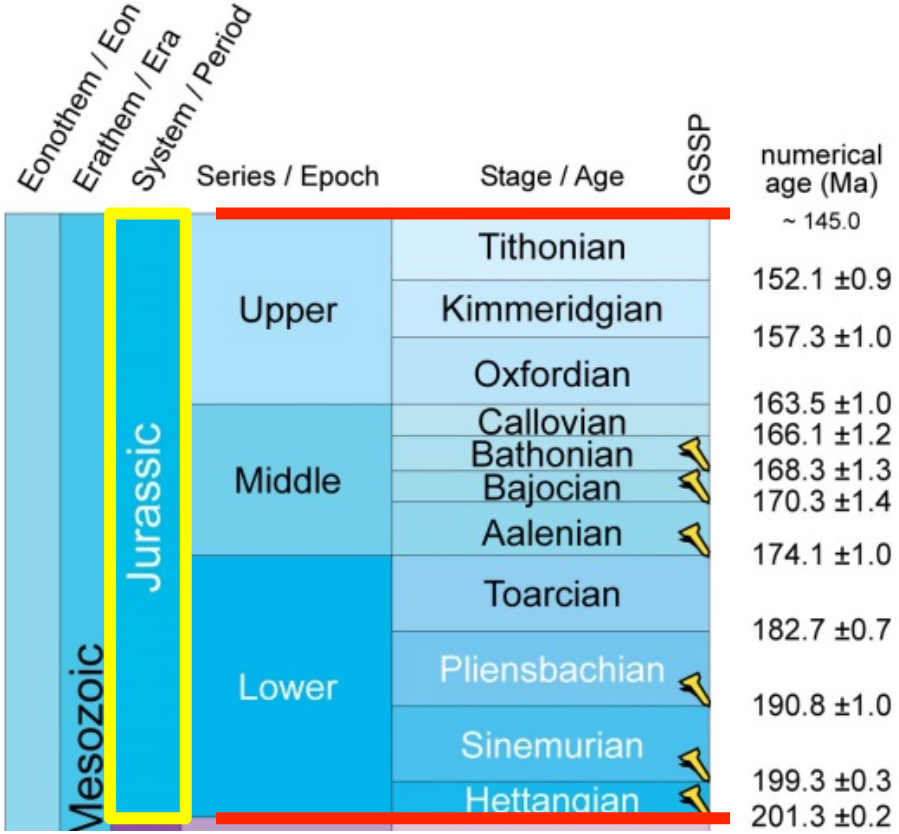
Geologic time




INTERNATIONAL CHRONOSTRATIGRAPHIC CHART
IUGS
www.stratigraphy.org
v 2014/02
Phanerozoic
Cenozoic
Mesozoic
Paleogene
Neogene
Quaternary
Cretaceous
Holocene
Upper
Middle
Berriasian
~ 139.8
~ 145.0
Tithonian
Kimmeridgian
Oxfordian
Callovian
Bathonian
Bajocian
Aalenian
Toarcian
Sinemurian
Hettangian
Rhaetian
Norian
Carnian
Ladinian
Anisian
Olenekian
Induan
Capitanian
Wordian
Roadian
Kungurian
Artinskian
Sakmarian
Asselian
Gzhelian
Moscovian
Bashkirian
Visean
Tournaisian
Lower
346.7 ±0.4
358.9 ±0.4
330.9 ±0.2
323.2
315.2
Ediacaran
Cryogenian
Tonian
Stenian
Ectasian
Calymmian
Neo-proterozoic
~ 635
850
1000
1200
1400
1600
1800
2050
2300
~ 541.0 ±1.0
Age
Stratum
Layer
Unit
Section
Point
Boundary
… …
UTAH
1896
CROSSROADS OF THE WEST
2007
E PLURIBUS UNUM
JFM
CCGM
CGMW
February 2014
Gibbard, P.L. & Fan, J.-X. (2013; updated)
Chart. Episodes 36: 199-204.
org/ICSchart/ChronostratChart2014-02.pdf

Geologic time scale – a framework

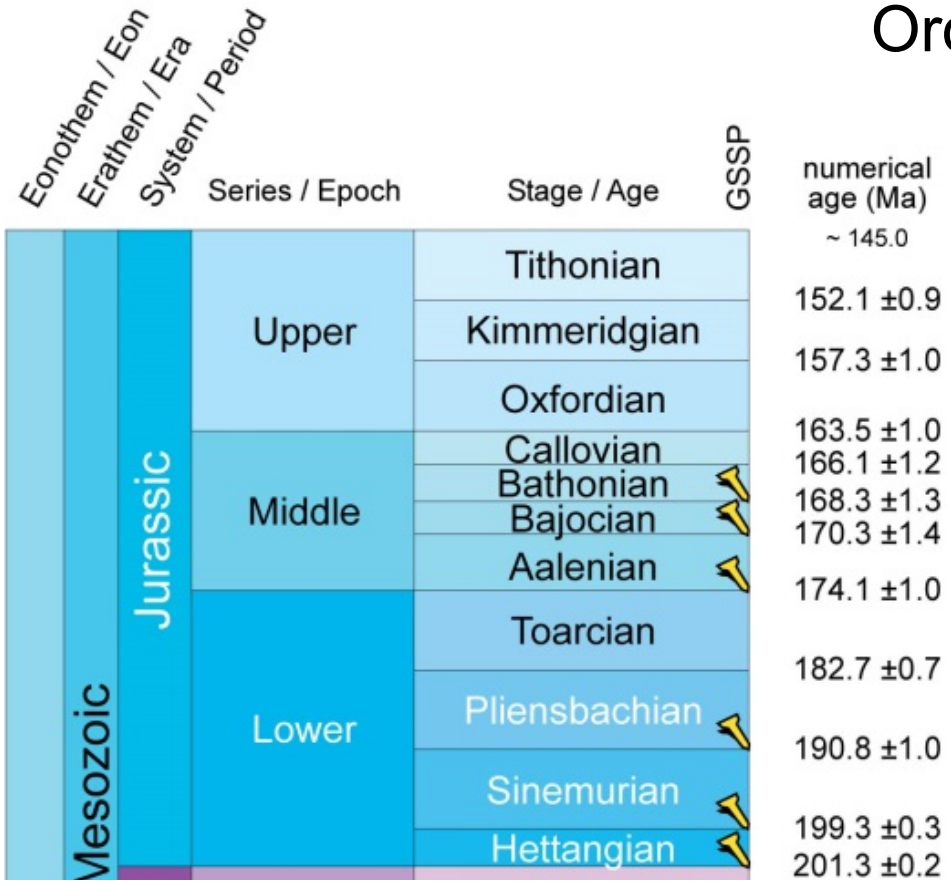
- Two key concepts
  - **Interval**: a period of time between two events
  - **Instant**: a particular point in time



We can see Jurassic as an Interval and its start and end time (base and top boundary) each as an Instant

Geologic time scale – a framework

Ordinal hierarchical structure



young

Ordinal

old

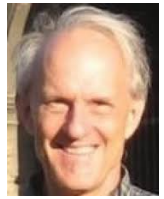
Hierarchical

broad → narrow

Encode the ordinal structure

The temporal position of the base of Jurassic

```
isc:Jurassic
   thors:begin       isc:BaseJurassic ;
   thors:end         isc:BaseCretaceous .

isc:BaseJurassic
   tm:temporalPosition    isc:BaseJurassicTime ;
   gts:stratotype         isc:GSSPBaseJurassic ;
   thors:nextEra          isc:Jurassic ;
   thors:previousEra      isc:Triassic .

isc:BaseJurassicTime
   tm:value                          "201.3"^^xsd:float ;
   thors:positionalUncertainty isc:BaseJurassicUncertainty.

isc:BaseJurassicUncertainty
   basic:value       "0.2"^^xsd:float .
```



Credit: Simon Cox
Steve Richard

http://resource.geosciml.org/vocabulary/timescale/isc2014.ttl

Encode the hierarchical structure

Location of Jurassic in the hierarchy of geologic time scale


```
isc:Jurassic
   gts:rank          gts:Period ;
   skos:broader      isc:Mesozoic ;
   skos:narrower     isc:LowerJurassic ;
   skos:narrower     isc:MiddleJurassic ;
   skos:narrower     isc:UpperJurassic .

isc:Mesozoic
   gts:rank          gts:Era ;
   skos:broader      isc:Phanerozoic ;
   skos:narrower     isc:Cretaceous ;
   skos:narrower     isc:Jurassic ;
   skos:narrower     isc:Triassic .
```

http://resource.geosciml.org/vocabulary/timescale/isc2014.ttl

Encode the information of golden spike

Golden spike of the base of Jurassic

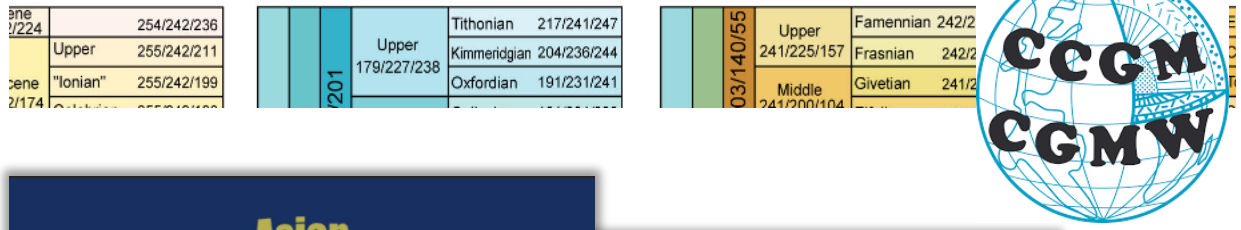
```
isc:BaseJurassic
  tm:temporalPosition      isc:BaseJurassicTime ;
  gts:stratotype           isc:GSSPBaseJurassic .

isc:GSSPBaseJurassic
  sam:shape   isc:BaseJurassic-location ;
  dc:source   "Episodes 36/3, p. 162-198, 2013"^^xsd:string ;
  gts:boundaryLevel        "5.80 m above top of Koessen
                           Formation"^^xsd:string .

isc:BaseJurassic-location
  gm:position        isc:BaseJurassic-position

isc:BaseJurassic-position
  gm:coordinates     "47.4839 11.5306"^^basic:ordinates ;
  gm:srs             <http://www.opengis.net/def/crs/EPSG/0/4326>.
```

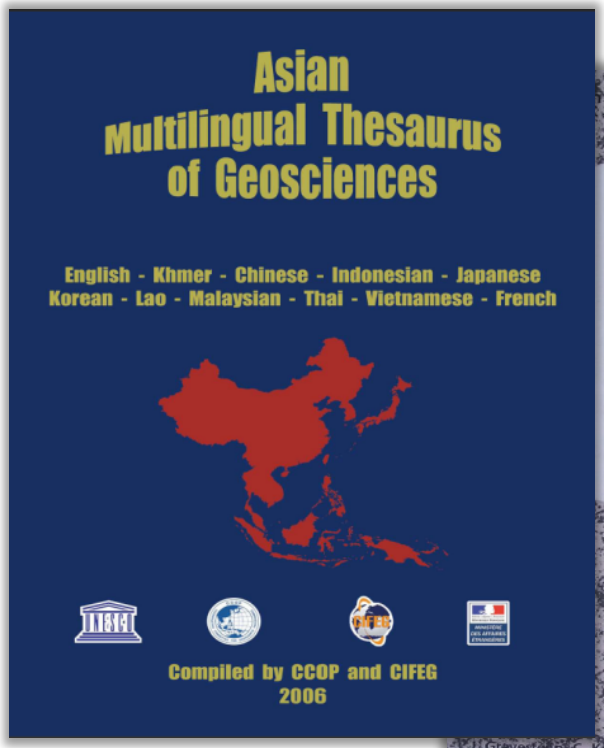
http://resource.geosciml.org/vocabulary/timescale/isc2014.ttl

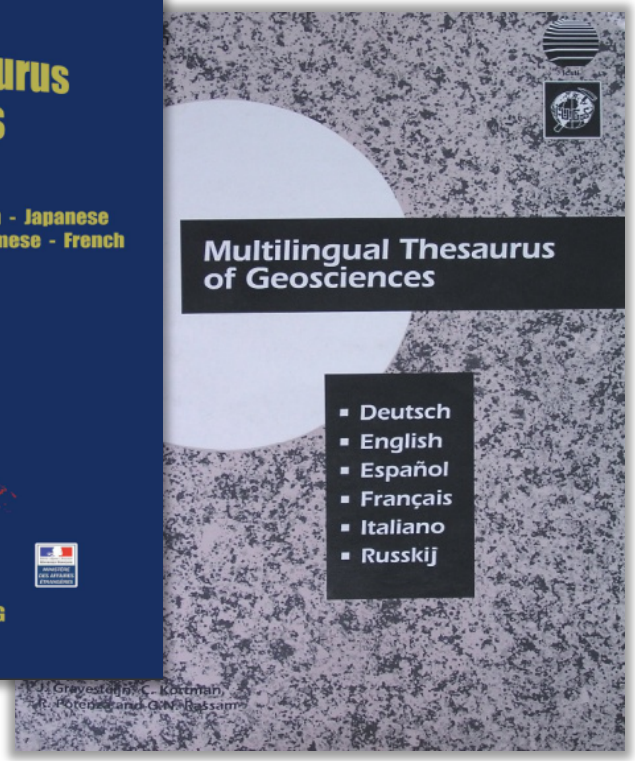
Different color spectrums for geologic time

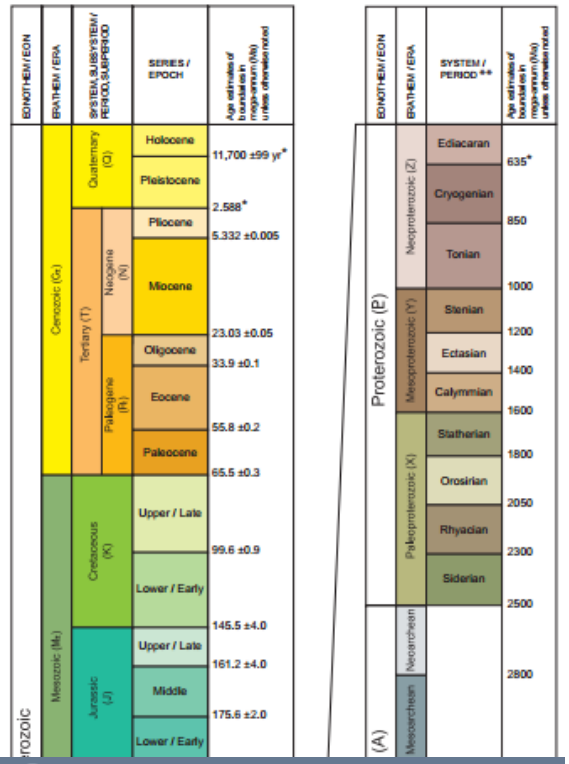
Multilingual labels of geologic time concepts

RGB Color Code according to the Commission for the Geological Map of the World (CGMW), Paris, France



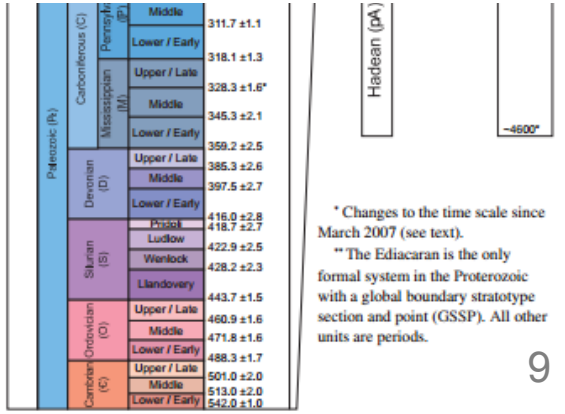






USGS
science for a changing world

Divisions of Geologic Time—
Major Chronostratigraphic and Geochronologic Units



* Changes to the time scale since March 2007 (see text).

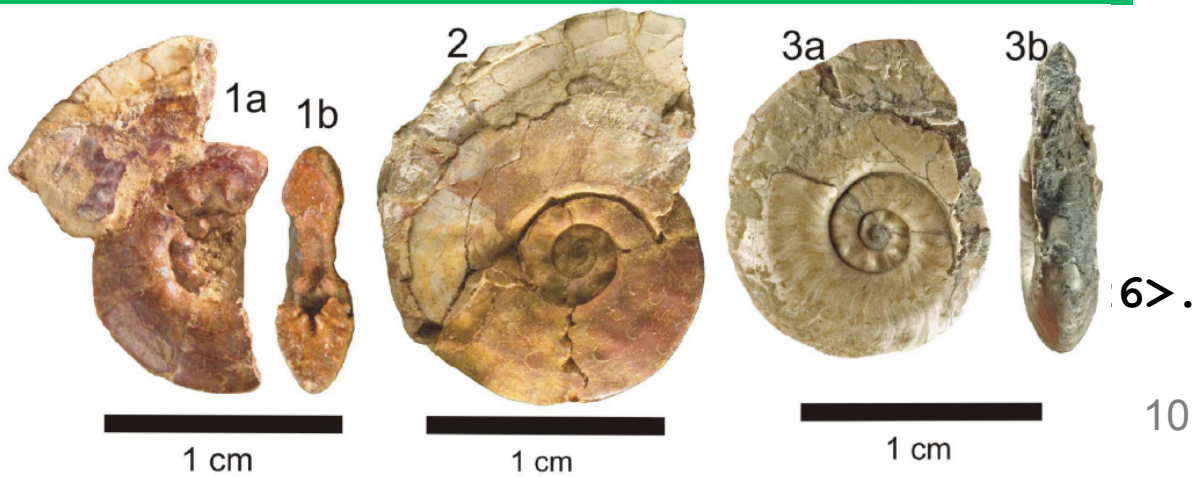
** The Ediacaran is the only formal system in the Proterozoic with a global boundary stratotype section and point (GSSP). All other units are periods.

More expressivity?

Golden spike of the base of Jurassic

```
isc:BaseJurassic
   tm:temporalPosition        isc:BaseJurassicTime ;
   gts:stratotype             isc:GSSPBaseJurassic .

isc:GSSPBaseJurassic
   sam:shape   isc:BaseJurassic-location ;
   dc:source   "Episodes 36/3, p. 162-198, 2013"^^xsd:string ;
   gts:boundaryLevel          "5.80 m above top of Koessen

isc:BaseJurassic-locati
   gm:position          isc

isc:BaseJurassic-positi
   gm:coordinates     "47
   gm:srs             <ht                                  6>.
```

The level of the golden spike coincides with the lowest occurrence of ammonite *Psiloceras spelae*

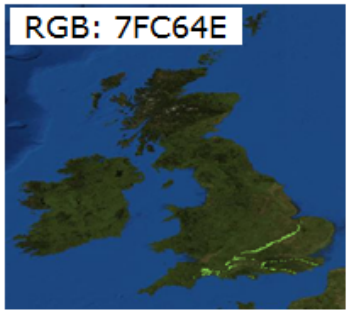


http://resource.geoscir

Reasoning and Inference

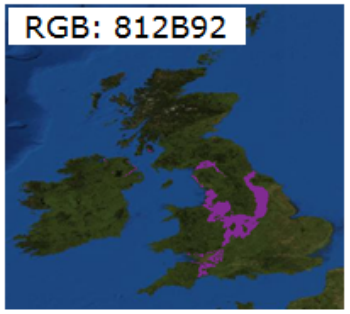
- Use reasoning to debug the statements (e.g. start age should be older than end age)
- Can we deduce the hierarchical and ordinal relationships between concepts using existing information (e.g., rank, start and end ages), rather than write all the statements
- Can we get the address of a golden spike, e.g., nation->region->town, using its coordinates (Google maps already have this, but how about LOD)

Filter & generalize geological time features

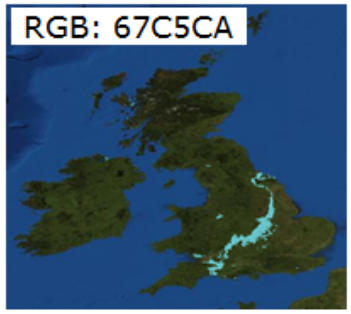


(a) Cretaceous

(b) Jurassic



(c) Triassic

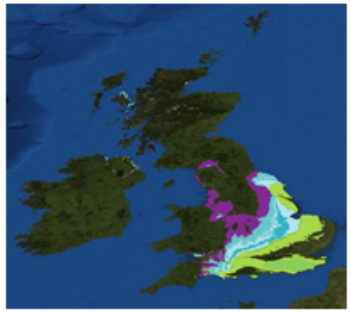


(d) Mesozoic

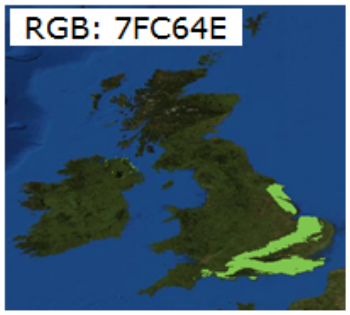
(e) Cretaceous after semantic inference

(f) Jurassic after semantic inference

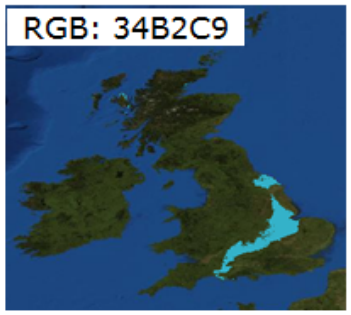
(g) Triassic after semantic inference



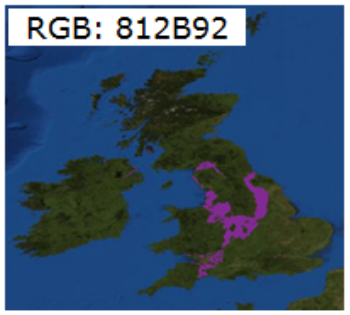
(h) Mesozoic after semantic inference



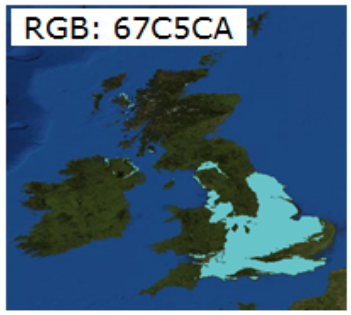
(i) Cretaceous after generalization



(j) Jurassic after generalization

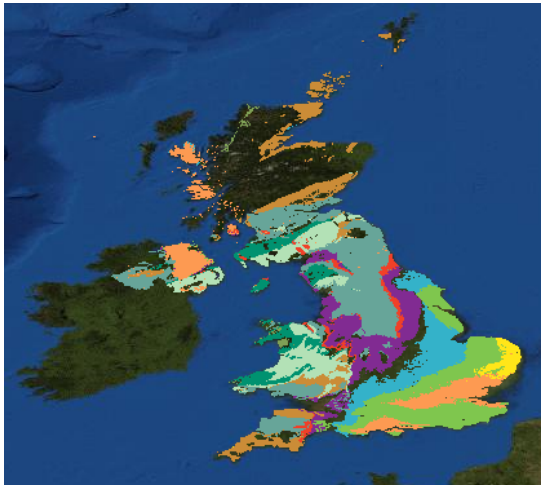


(k) Triassic after generalization

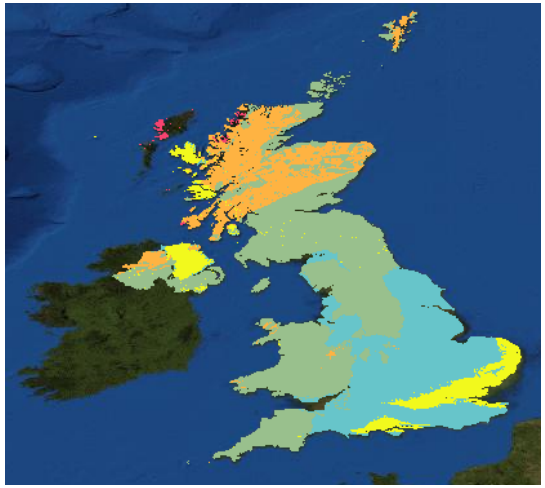


(l) Mesozoic after generalization

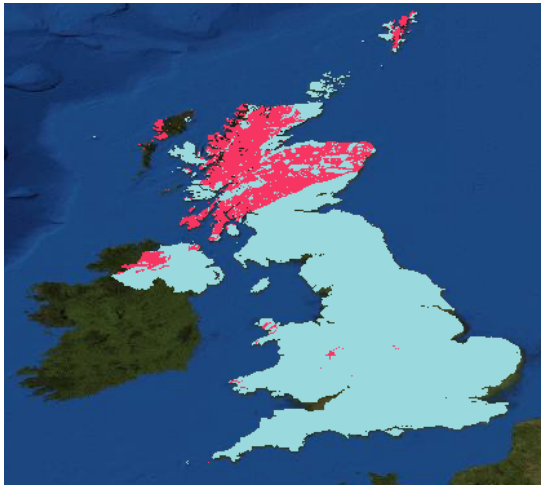
More examples of map generalization



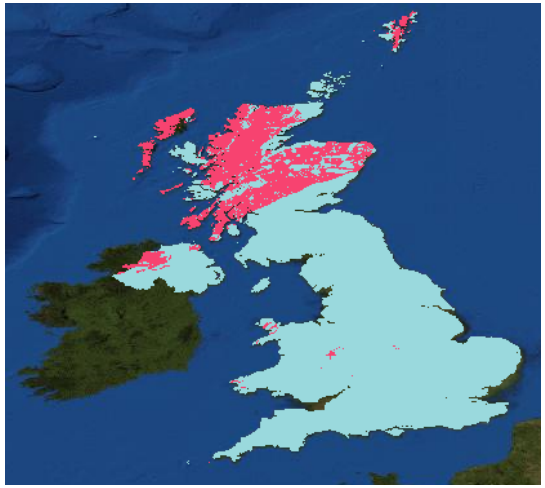
Generalization at System level



Generalization at Erathem level

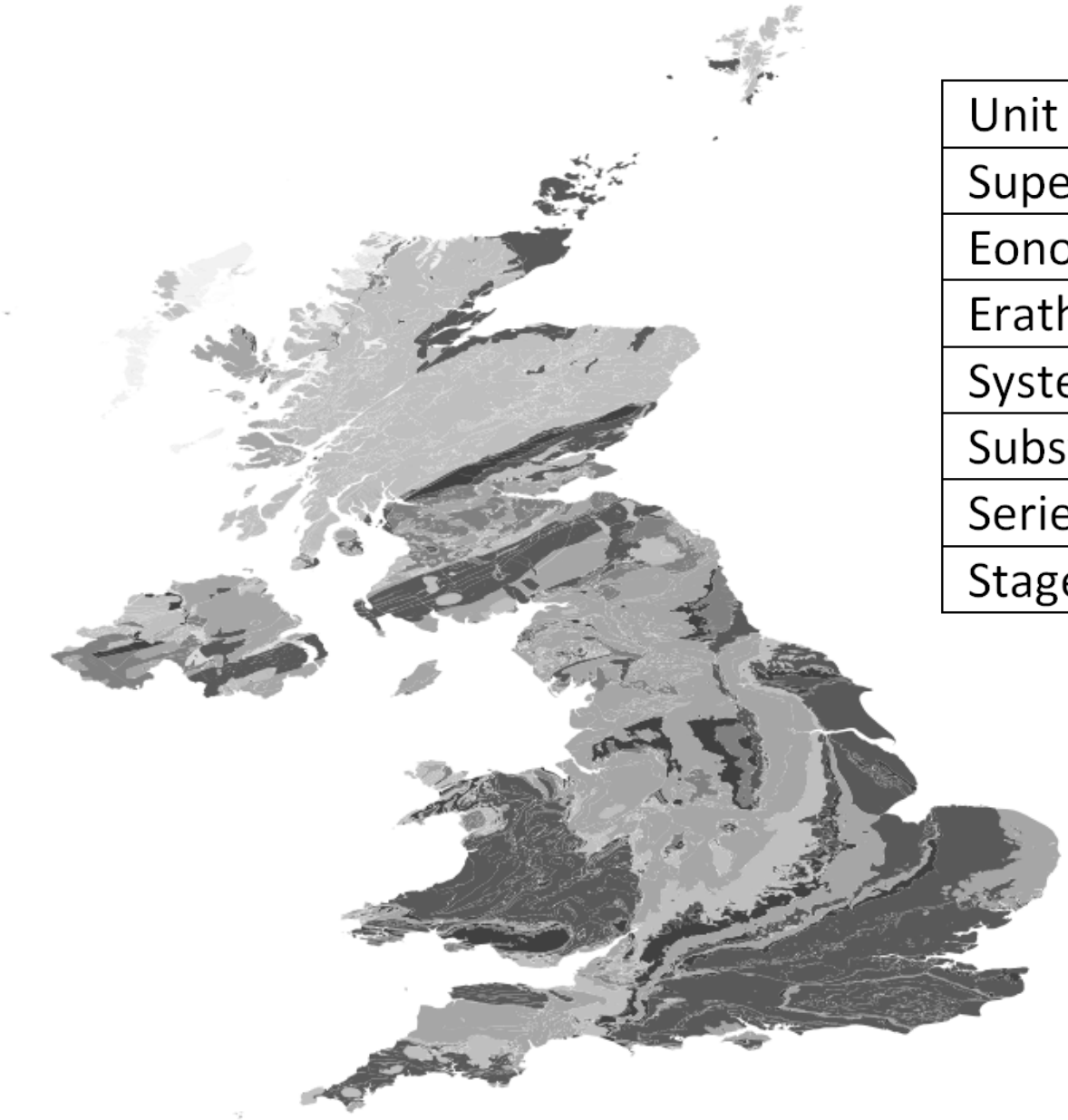


Generalization at Eonothem level



“Precambrian” and “Phanerozoic”

Another type of map generalization / data analysis

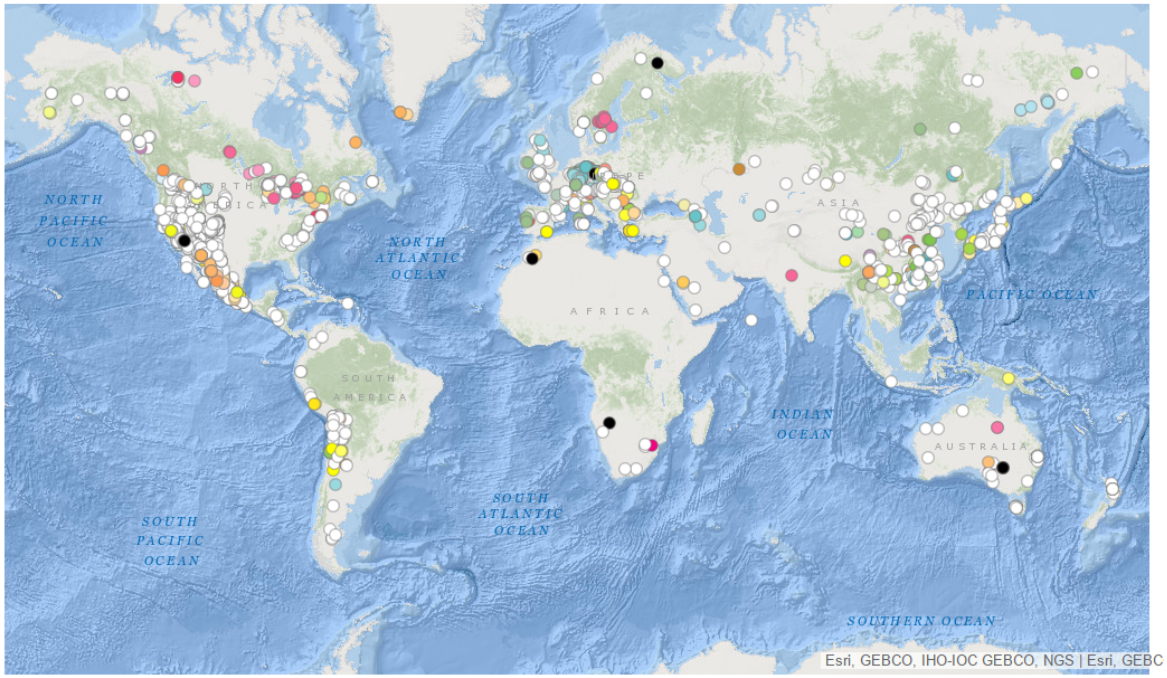


Unit	Color
Supereonothem	
Eonothem	
Erathem	
System	
Subsystem	
Series	
Stage	

Search mineral observation records

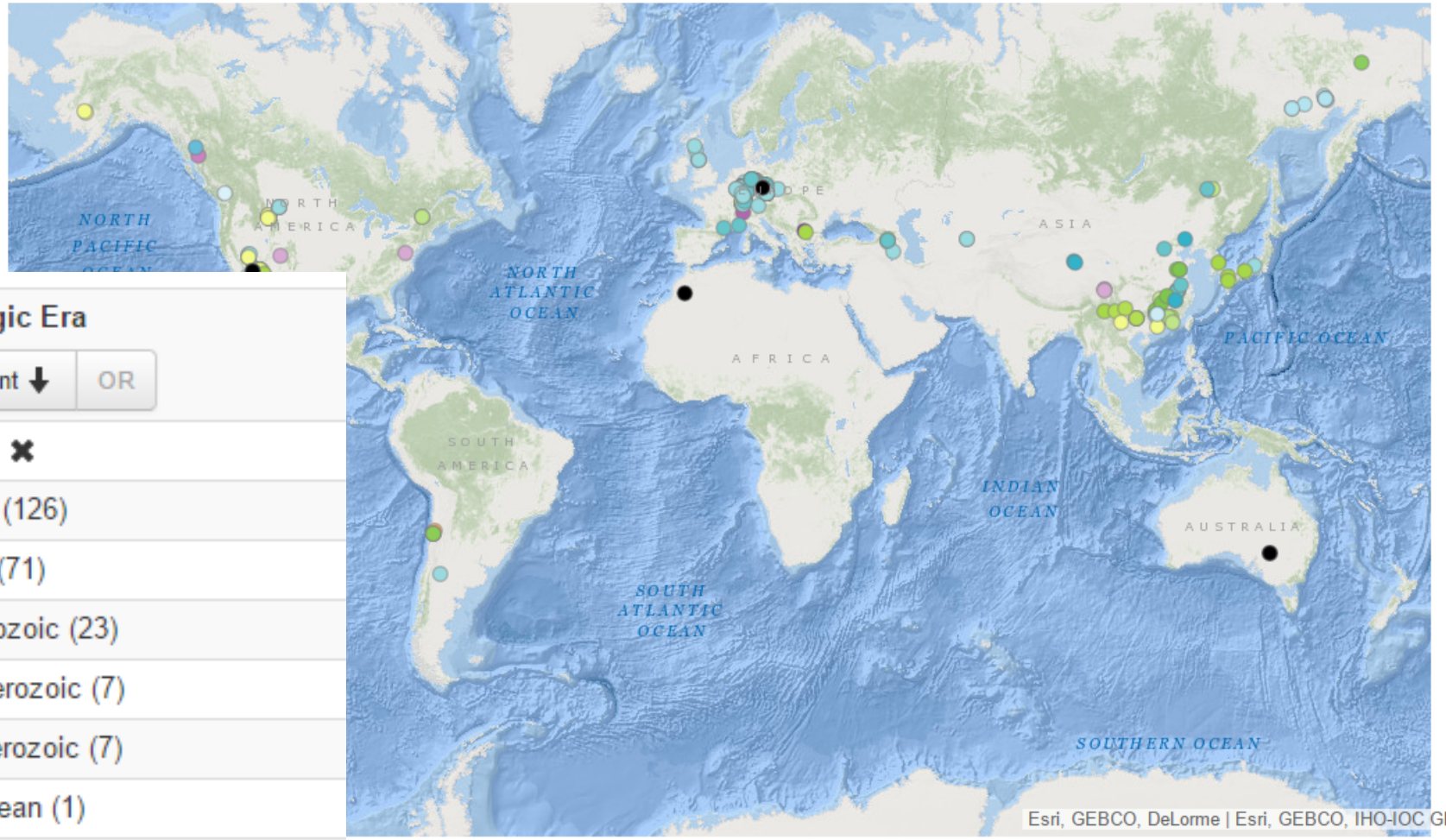
- + Mineral Name
- + Mineral Elements
- + Geologic Eon
- + Geologic Era
- + Geologic Period
- + Geologic Epoch
- + Geologic Stage
- + Country
- + Region
- + Locality

search term



Under development: https://deeptime.tw.rpi.edu/map/map.html

Search mineral observation records



− Geologic Era

15 | count ↓ | OR

- **Mesozoic ✖**
- Paleozoic (126)
- Cenozoic (71)
- Neoproterozoic (23)
- Paleoproterozoic (7)
- Mesoproterozoic (7)
- Paleoarchean (1)
- Neoarchean (1)
- Mesoarchean (1)
- Eoarchean (1)

Thank you!

More information:
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